AD-A007 803

DECISION RISK ANALYSIS OF PICATINNY AND MILAN DEVELOPMENTAL MELT-POUR PROCESSES

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Army Armament Command
Rock Island, Illinois

January 1975

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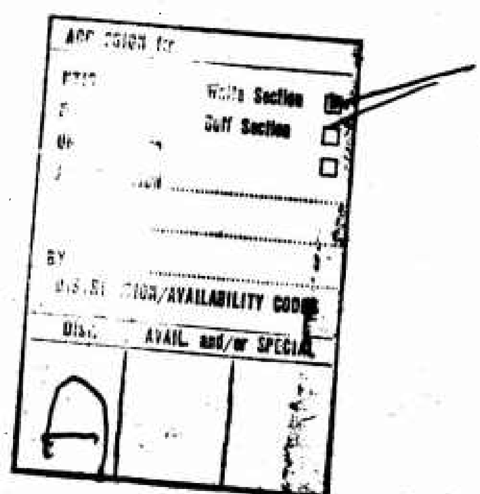

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Picatinny and Milan developmental melt-pour processes were analyzed to determine their suitability as alternatives to the current melt-kettle method of cast-loading explosive fills. Estimated comparisons were made pertaining to safety potential of each type of process.

Conclusion: There was only a minimal chance of reducing potential fatalities, disabling injuries, and property damage by replacing the current melt-pour facilities with either the Picatinny or Milan processes.

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SUMMARY

The Picatinny and Milan developmental melt-pour processes were analyzed (as requested by DF from AMSAR-MT, Appendix A) to determine their suitability as alternatives to the current melt-kettle method of cast-loading explosive fills. This analysis assumed replacement of the current process with these proposed processes and compared estimates of the fatalities, disabling injuries, and property damage that might occur in the event of an explosion in the melt-pour building. The safety potential of each type of process was the only factor that could be evaluated because no significant differences between proposed and current processes could be determined for production capabilities and operational costs.

The safety parameter was taken as a function of the Mean-Time-Between-Explosions (MTBE) individually for each process at each location. There was only a minimal chance of reducing potential fatalities, disabling injuries, and property damage by replacing the current melt-pour facilities with either the Picatinny or Milan processes. The chance of achieving this reduction was directly contingent upon the probability of an explosion occurring in the melt-pour process and the expectation of this happening was highly improbable for the wide range of Mean-Time-Between-Explosions (MTBE's of 10, 50 and 100 years) used in this evaluation.

There was statistically no chance of achieving a favorable savings investment ratio unless a current process with a very low MTBE was replaced by the Milan system. The Milan developmental process has a lower replacement cost potential than the larger and more expensive Picatinny process.

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STATEMENT OF PROBLEM

The proposed Picatinny continuous and Milan "Minute Melter" melt-pour processes were examined to determine their suitability as alternatives to the current method of cast-loading explosive fills.

Consideration was given to the following:

- Current state of development of the new processes.
- Potential of the new processes for melt-loading various types of explosive fills (Composition B, TNT, and AMATEX).
- Identification of the Load, Assemble, and Pack (LAP) facilities and the munitions for which the new processes would be most beneficial.
- Probable operating costs for the new processes.
- Potential safety advantages of the new melt-pour processes.

BACKGROUND

The cast-loading of explosive fills in ammunition items is now accomplished by basically manual operations involving large numbers of personnel and large amounts of in-process explosive. The present facilities were designed and built in the early 1940's, and it is planned to modernize them with a new generation of material handling equipment and automatic, remotely-controlled melt-pour units.

Currently, the melt-pouring of the explosive fills is done in large three-story melt-towers whose melt kettles may be batch-processing 15,000 or more pounds of explosive. This operation may employ, depending on the item being loaded, as many as two to three dozen workers within the melt-tower and attached cooling bays.

Two developmental melt-pour processes have been proposed as potential replacements for the current melt-kettle technique: (1) a continuous "porcupine" type melt system developed by Picatinny Arsenal, and (2) a rapid batch-type "Minute Melter" system developed at the Milan Army Ammunition Plant (AAP). Both systems are designed to be operated with significantly lower quantities of in-process explosive and will be automatically operated from a remote control center in order to eliminate personnel from the most dangerous part of the melt-pour operation.

ALTERNATIVES

The present melt-pour process uses large steam-heated grids and 150- or 300-gallon Dopp kettles to melt large batches of explosives. It is basically a manual operation, using 10 to 20 or more personnel. In the melt-towers explosive allowances range, depending on the production rate and the item being loaded, from 3000 to 30,000 or more pounds. Large quantities of in-process explosive are necessary in this system because the Dopp kettles are highly inefficient melters - having a very small heat transfer surface with respect to their volume.

The Picatinny Arsenal process will use indirect steam to melt and pour explosive in a continuous, rather than batch-type, manner. This system will be completely automated and remotely controlled in order to eliminate workers and decrease the safety hazards. As designed for use in the new 105mm LAP complex proposed for line E at the Lone Star AAP, this process will have a production capability of 9000 pounds of explosive per hour and an in-process limit of 2500 pounds for the melting unit. The distinguishing characteristics of this system are: (1) a continuous-type melting unit whose steam-heated "porcupine" agitator has a greater surface area than the vessel's steam-heated jacket, (2) a heated piping system which pumps the melted explosive from the bottom of the melter to the separately located volumetric pouring unit, and (3) a separate melter for the riser scrap.

The Milan "Minute Melter" system will be an automated, remotely-controlled, batch-type process using direct saturated steam to rapidly melt small amounts of explosive. Developed to handle the smaller items loaded at the Milan AAP, this process was initially designed to have a production rate of 60 pounds of explosive per minute or 3600 pounds per hour. A complete "Minute Melter" module consists of one melting drum and two separate conditioning drums. The function of the conditioners is to remove the condensate and prepare the explosive for pouring; two of these units are needed because their cycle time is twice as long as the melting cycle. Because this system handles small batches very rapidly, the amount of in-process explosive (about 200 pounds or less) and the associated quantity-distances are very small. This process is now being installed in line C at Milan. A separate melter is not required for the riser scrap.

Figures 1 through 3 are flow diagrams showing the relationship of these alternative processes within a typical melt-pour LAP line.

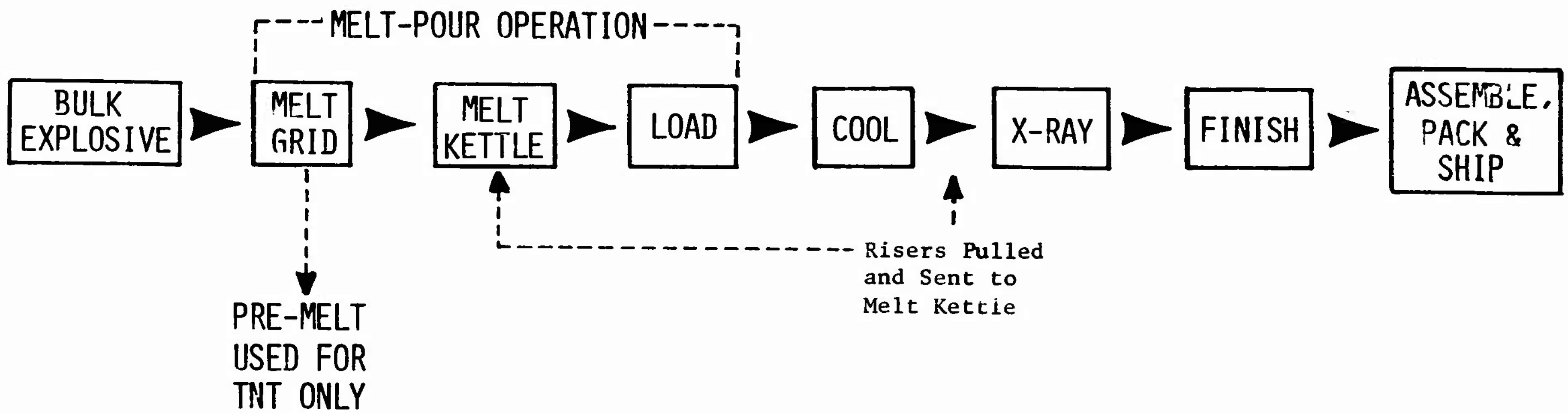

Figure 1. Lap Line With Current Melt-Pour Process

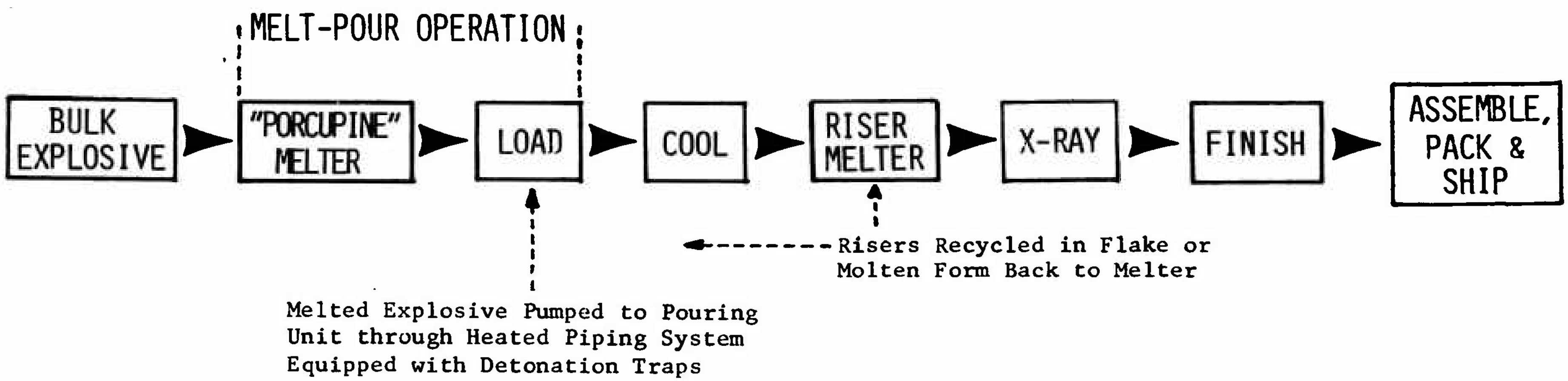

Figure 2. Lap Line With Picatinny Melt-Pour Process

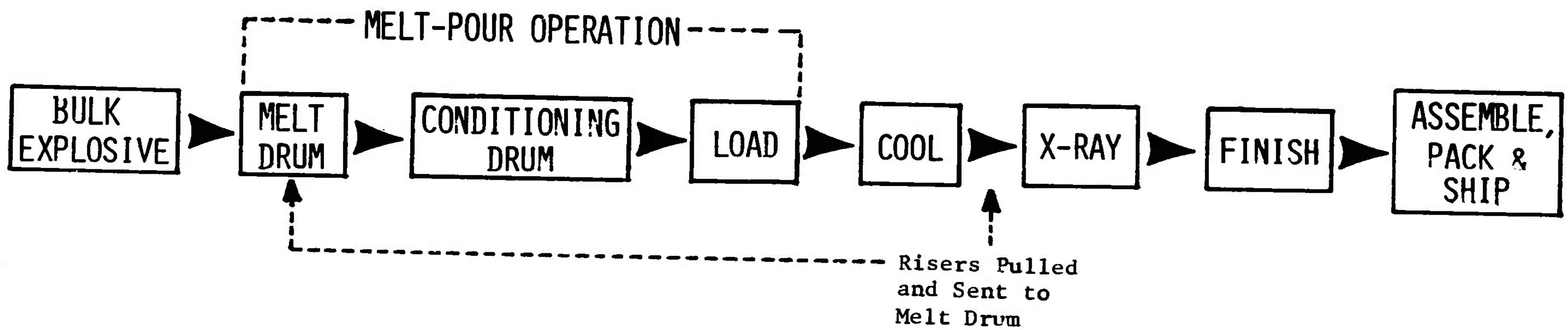

Figure 3. Lap Line With Minute Melter Melt-Pour Process

ASSUMPTIONS

Both of the new processes are at the same level of development with a like probability of success.

Both of the new processes can handle TNT and Composition B explosive fills, but the Industrial Management Division, AMSAR-PPI (formerly Manufacturing Technology Directorate, AMSAR-MT), indicated that further research is required by Picatinny Arsenal before a decision can be made about Amatex, an ammonium nitrate type of explosive being considered as an alternative for Composition B.

Penalty costs for lost production due to an explosion would probably be insignificant according to AMSAR-PPI. If possible, the balance of the production would be shifted to another active line at the same plant. The startup and layaway costs for an inactive line are fairly standard and may be minimal if prorated over a normal one year production period.

The evaluation of the safety potential of each process was based on ARMCOM Safety Office estimates of the damage and casualties that might result from an explosion in the melt-pour building.

METHODOLOGY

Safety was the only criteria used to evaluate the current and proposed melt-pour processes. AMSAR-PPI indicated that the differences in the production capabilities and operational costs would not be significant; therefore, they were not considered in this analysis. The safety potential of each process was parametrically and stochastically analyzed in terms of the fatalities, disabling injuries, and property damage replacement costs that might occur if there was an explosion in the melt-pour building. The proposed processes were compared with the current melt-kettle technique at six LAP lines using a computer model to simulate each facility combination and provide comparative results.

A lack of information about the explosive accidents at the melt-pour plants made it necessary to estimate the damage and casualties and to parameterize the mean-time to next explosion. The results obtained with both models were based on 1000 iterations for each process combination.

Appendix B contains a detailed description and flow diagram of the computer model. The model is divided into two parts as follows:

Part 1

This part simulated the activity of the current and the two

proposed processes at each of six LAP lines (two each at Iowa, Joliet, and Milan AAP's) using parametric values to stochastically derive the cost comparison inputs required for the second part of the model.

Inputs - (Detailed in Appendix C)

- Cost per fatality ($75,000) and disabling injury ($3,200).
- Cost per building and its IPE.
- Triangular distribution of fatalities, injuries, and property damage resulting from an explosion in the melt-pour process.
- Population (manning level) for each LAP line.
- MTBE's of 10, 50, and 100 years.
- 10 percent discount factor.

Constraints -

- Only explosions randonly occurring within a 10-year period of operation (the assumed economic life of the equipment) were used in this analysis.*
- 1000 "Monte Carlo" iterations per case.
- Casualty-damage zones based on quantity-distances for maximum explosive limits in the melt-pour building of 15,000 pounds for current process, 2,000 pounds for Picatinny process, and 200 pounds for Milan process.

Outputs -

- Expected value, variance and histogram of the fatalities, injuries and replacement costs for each process comparison.

Part 2

This part used "Monte Carlo" techniques to compare the variates obtained in Part 1 for the current process with those obtained for the proposed processes. The like variates were randomly selected for each process (proposed and current) and the difference between the two was calculated. In order to calculate a savings investment

* This assumption was based on guidance furnished by AMSAR-PPI.

ratio (SIR) for each process comparison, this portion of the model also considered investment costs in addition to the other inputs.

Inputs -

- Histograms of the fatalities, disabling injuries, and costs for current and proposed process being compared by each combination.
- Distribution parameters of investment costs for proposed processes.

Constraints -

- 1000 Monte Carlo iterations per case (current-proposed process comparison at various combinations of MTBE's).

Output -

- Expected value, variance and histogram of the reduction in fatalities, injuries, and costs and the savings investment ratio (SIR) for the proposed processes compared with the current process at each location.

RESULTS

This analysis evaluated the safety potential of the new processes by assuming replacement of the current melt-pour techniques with the proposed Picatinny and Milan processes and compared estimates of the casualties and damage that might occur at specified quantity-distances in the event of an explosion in the melt-pour building. AMSAR-PPI has indicated that replacement of the current melt-pour facilities with either of the new processes should increase the safety potential of the cast-loading process, by significantly reducing the amount of in-process explosive and removing personnel from the melt-pour building. Since the differences in the production capabilities and operational costs could not be shown to be significantly different, safety was the only factor that could be analyzed. The safety potential was considered to be dependent on the probability of explosion expressed as the Mean-Time-Between-Explosions (MTBE). Results were determined for three levels of MTBE (10, 50, and 100 years) at six LAP lines for both the current and each replacement process. A condensation of the results is presented in Tables 1, 2, 3, and 4. The detailed results for all of the process combinations are in Appendix D.

Fatalities

The expected decrease in fatalities - while always positive - was not exceptional at any combination or reliabilities. It was only

TABLE 1. CONDENSATION OF RESULTS -

OBSERVATION	OBSERVATION NOT		
	JOLIET AAP		
	GROUP 2	GROUP 3	LINE 2
Expected Reduction in Fatalities > 0	*	*	*
Probability of Reduction in Fatalities > 0	*	*	*
Risk of Increase in Fatalities > 0	** $MTBE_p \geq MTBE_c$	$MTBE_p \geq MTBE_c$	$MTBE_p = 100$ $MTBE_c = 10$
Probability of a Reduction in Fatalities > Risk of Increase in Fatalities	$MTBE_p \geq MTBE_c$	$MTBE_p \geq MTBE_c$	$MTBE_p \geq MTBE_c$

* Observation occurred at all conditions examined.

** $MTBE_p$ - Mean-Time-Between-Explosion, proposed process

$MTBE_c$ - Mean-Time-Between-Explosion, current process (values, when given, are in years)

ENSATION OF RESULTS - FATALITIES

	OBSERVATION NOTED WHEN			
	IOWA AAP		MILAN AAP	
	LINE 2	LINE 3	LINE C	LINE D
	*	*	*	*
	*	*	*	*
c	$MTBE_p$ = 100 yrs $MTBE_c$ = 10 yrs	$MTBE_p > MTBE_c$	$MTBE_p > MTBE_c$	$MTBE_p$ = 100 yrs $MTBE_c$ = 10 yrs
c	$MTBE_p \geq MTBE_c$	$MTBE_p > MTBE_c$	$MTBE_p > MTBE_c$ and $MTBE_c <$ 100 yrs	$MTBE_p > MTBE_c$ and $MTBE_c <$ 100 yrs

n given, are in years)

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TABLE 2. CONDENSATION OF RESULTS - INJURI

OBSERVATION	OBSERVATION NOTED		
	JOLIET AAP		IOWA A
	GROUP 2	GROUP 3	LINE 2
Expected Reduction in Injuries > 0	$MTBE_p \geq MTBE_c$ & all $MTBE \geq 50$ yrs	$MTBE_p \geq MTBE_c$ & all $MTBE \geq 50$ yrs	$MTBE_p \geq MTBE_c$
Probabilities of Reduction in Injuries > 0	*	*	*
Risk of Increase in Injuries > 0	*	*	*
Probability of Reduction > Risk of Increase in Injuries	$MTBE_p \geq MTBE_c$	$MTBE_p \geq MTBE_c$	$MTBE_p \geq MTBE_c$

* Observation occurred at all conditions examined.

ENSATION OF RESULTS - INJURIES

	OBSERVATION NOTED WHEN			
	IOWA AAP		MILAN AAP	
	LINE 2	LINE 3	LINE C	LINE D
& yrs	$MTBE_p \geq MTBE_c$	$MTBE_p \geq MTBE_c$	$MTBE_p \geq MTBE_p$ & all $MTBE_c \geq$ 50 yrs	$MTBE_p \geq MTBE_c$
	*	*	*	*
	*	*	*	*
	$MTBE_p \geq MTBE_c$	$MTBE_p \geq MTBE_c$	$MTBE_p \geq MTBE_c$	$MTBE_p \geq MTBE_c$

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TABLE 3. CONDENSATION OF RESULTS - SAVINGS (R

OBSERVATION	CORRESPONDING CONDI		
	JOLIET AAP		IOWA
	GROUP 2	GROUP 3	LINE 2
Expected Cost Saving for Minute Melter > 0	$MTBE_p \geq$ 50 years or $MTBE_c \leq$ 10 years	$MTBE_p \geq$ 50 years or $MTBE_c \leq$ 10 years	$MTBE_p \geq$ 50 years or $MTBE_c \leq$ 10 years
Expected Cost Savings for Picatinny Process > 0	$MTBE_p \geq$ 50 years $MTBE_c \leq$ 10 years	$MTBE_p \geq$ 50 years $MTBE_c \leq$ 10 years	$MTBE_p \geq MTBE_c$
Probability of Savings for Minute Melter > 0	*	*	*
Probability of Savings for Picatinny Process > 0	*	*	*
Risk of Increase in Cost Using Minute Melter > 0	*	*	*
Risk of Increase in Cost Using Picatinny Process > 0	*	*	*
Probability of Savings > Risk of Cost Increase - Minute Melter	$MTBE_p \geq MTBE_c$	$MTBE_p \geq MTBE_c$	$MTBE_c <$ 100 years & $MTBE_p \geq MTBE_c$
Probability of Savings > Risk of Cost Increase - Picatinny Process	$MTBE_p \geq MTBE_c$	$MTBE_c <$ 100 years & $MTBE_p \geq MTBEc$	$MTBE_c <$ 100 years & $MTBE_p \geq MTBE_c$
Expected Savings - Milan Process > Expected Savings - Picatinny Process	*	*	*

* Observation occurred at all conditions examined.

OF RESULTS - SAVINGS (REPLACEMENT COSTS)

	CORRESPONDING CONDITION AT EACH LOCATION			
	IOWA AAP		MILAN AAP	
	LINE 2	LINE 3	LINE C	LINE D
s ars	$MTBE_p \geq$ 50 years or $MTBE_c \leq$ 10 years	$MTBE_p \geq$ 50 years $MTBE_c \leq$ 10 years	$MTBE_p \geq$ 50 years $MTBE_c \leq$ 10 years	$MTBE_p \geq$ 50 years $MTBE_c \leq$ 10 years
s s	$MTBE_p \geq MTBE_c$	$MTBE_p \geq MTBE_c$	$MTBF_p \geq MTBE_c$	$MTBE_p \geq MTBE_c$
	*	*	*	*
	*	*	*	*
	*	*	*	*
	*	*	*	*
	$MTBE_c <$ 100 years & $MTBE_p \geq MTBE_c$	$MTBE_c <$ 100 years & $MTBE_p \geq MTBE_c$	$MTBE_c <$ 100 years $MTBE_p \geq MTBE_c$	$MTBE_c <$ 100 years $MTBE_p \geq MTBE_c$
ars c	$MTBE_c <$ 100 years & $MTBE_p \geq MTBE_c$	$MTBE_c <$ 100 years & $MTBE_p \geq MTBE_c$	$MTBE_c <$ 100 years & $MTBE_p \geq MTBE_c$	$MTBE_c <$ 100 years & $MTBE_p \geq MTBE_c$
	*	*	*	*

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TABLE 4. CONDENSATION OF RESULT

OBSERVATION	CORRESPONDIN		
	JOLIET AAP		
	GROUP 2	GROUP 3	LI
Expected SIR 1.0 (Minute Melter)	$MTBE_c \leq$ 100 years	$MTBE_c \leq$ 10 years	$MTBE_c$
Expected SIR 1.0 (Picatinny Process)	*	*	
Probability of Achieving an SIR 1.0 with (Minute Melter) 0	**	**	
Probability of Achieving an SIR 1.0 with Picatinny Process	$MTBE_p \leq$ 10 years	$MTBE_p \leq$ 10 years	$MTBE_p$

* Observation did not occur at any conditions examined.
** Observation occurred at all conditions examined.

CONDENSATION OF RESULTS - SAVINGS INVESTMENT RATIO

CORRESPONDING CONDITION AT EACH LOCATION					
	IOWA AAP		MILAN AAP		
OUP 3	LINE 2	LINE 3	LINE C	LINE D
10 years	$MTBE_c \leq$ 10 years	$MTBE_c \leq$ 10 years	$MTBE_c \leq$ 10 years	$MTBE_c \leq$ 10 years & $MTBE_p \geq$ 10 years
*	*	*	*	*
**	**	**	**	**
10 years	$MTBE_p \leq$ 10 years	$MTBE_p \leq$ 10 years	$MTBE_p <$ 10 years	$MTBE_p <$ 10 years

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when the current process had a low reliability (MTBE = 10 years) that the potential reduction in fatalities reached higher levels, 10 percent or more of the work force. A review of all combinations indicated that the expected reductions in fatalities were primarily dependent upon the MTBE of the current process, and secondly, upon the location - the factor which determined the work force levels and replacement costs for each site.

Although the probability of a reduction in fatalities existed for all combinations of MTBE, there was also a risk that the replacement of the current process might increase casualties. This analysis showed that the probability of a reduction in fatalities is greater than the risk of an increase in fatalities if the current process is replaced with one having an equal or greater MTBE.

Under the MTBE's assumed for this study, replacement of the current processes with either one of the proposed new processes would not result in a significant chance of reducing fatalities.

Disabling Injuries

The potential effect of the process replacements on the number of disabling injuries followed the same pattern indicated for the fatalities. A decrease in injuries was indicated only when the safety potential of the current process was low (MTBE = 10 years); other wise, the probability of a reduction in injuries was minimal. The potential risk of an increase in injuries was also significant.

Property Damage Replacement Costs

Replacement costs results exhibited the same general correlation observed in the fatality and injury analysis. The probability of achieving a cost reduction generally exceeded the attendant risk of a cost increase when the MTBE of the new process was equal to or greater than that of the current facility. Like those observed for the fatalities and injuries, the probability of a reduction in replacement costs was generally minimal except when the MTBE of the present facility was low (e.g., 10 years).

The expected cost reduction potential for the Milan process was greater than that of the Picatinny system because the "Minute Melter" is smaller and has less in-process explosive.

Savings Investment Ratio (SIR)

The savings investment ratio obtained with the Picatinny process indicated that one could not expect to get a return on the investment in the form of cost savings. It was only when the MTBE of the current process was very low that there was even a probability of achieving a SIR = 1.

A favorable ratio was obtained with the smaller, less expensive Milan process when the current facility had a very low MTBE (10 years). Otherwise, there is a high risk that a ratio equal to/or exceeding unity cannot be attained even with the Milan process.

Probability of Explosion

The probability of achieving a change in the casualties and property damage costs is keyed to the probability of an explosion occurring in the current and new processes. Figure 4 shows the expectation of an explosion occurring during the range of MTBE's utilized in this study. At an MTBE of 100 years, the expectation of an explosion occurring during the assumed 10-year economic life of the process is only .10. Conversely, the probability of nothing happening is a significant .90. Since the expectation of an explosion occurring is a double exponential decaying function of reliability (MTBE), the chance of an explosion is highly improbable for the range of reliabilities (MTBE of 10 through 100 years) used in this study. The expected effects on the casualties and property damage tend to zero and the purported safety advantages of the new processes are significantly diminished.

CONCLUSIONS

Replacement of the current melt-pour process with either the Picatinny or Milan systems would not result in a significant chance of reducing potential fatalities, disabling injuries and property damage.

The chance of achieving this reduction is directly contingent upon the probability of an explosion occurring in the melt-pour process. The chances of an explosion are highly improbable for the range of reliabilities (MTBE's of 10, 50 and 100 years) assumed for this study.

The probability of achieving a reduction in the casualties and property damage is greater than the attendant risk of an increase if the reliability of the replacement process is equal to or greater than that of the current process.

There would be no significant probability of achieving a savings investment ratio of unity or greater unless a current facility with a very low reliability was replaced by the Milan process.

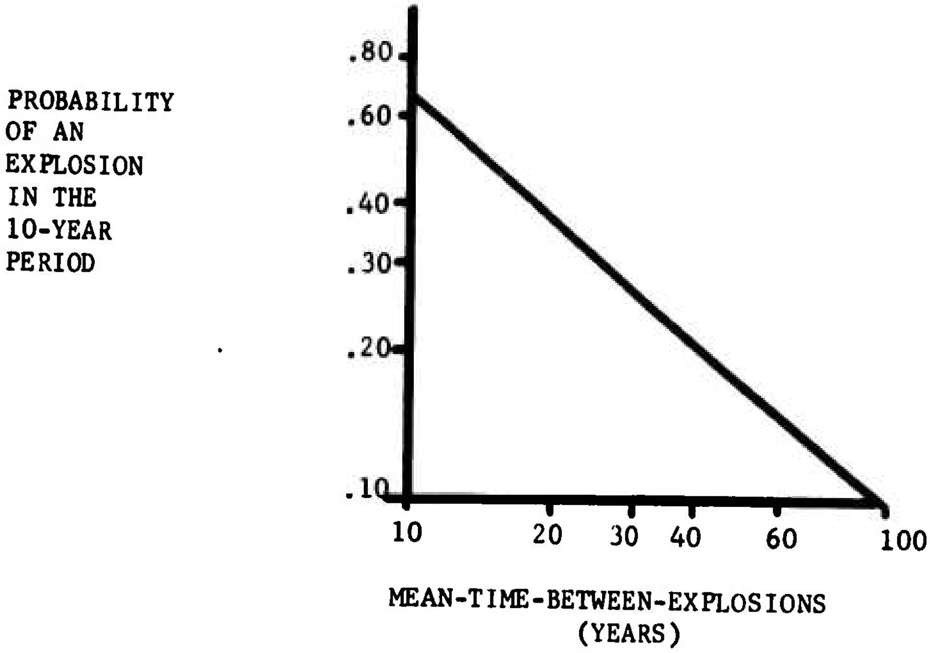

Figure 4. Expectation of an explosion occurring as a function of reliability.

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REFERENCE OR OFFICE SYMBOL	SUBJECT
AMSAR-MT	Melt-Pour Facilities

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1. Currently we have planned melt-pour facilities for the load assembly and pack plant in the neighborhood of $400,000.00 Picatinny Arsenal is working on a continuous melt-pour system. Also, Milan AAP is developing a mini-melter for low volume operations.

2. I request a AMSAR-SA evaluation of these systems with a recommendation as to possible application for adapting the mini-melter to various types of loading operations.

Daniel J. Benefiel

DANIEL J. BENEFIEL
Colonel, GS
Director, Manufacturing
Technology Directorate

CF:
Cdr, PA, Dover, NJ
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APPENDIX B

DESCRIPTION OF MODEL

The safety potential proved to be the only criterion that could be used to evaluate each process. It was simulated in terms of the fatalities, disabling injuries, and property damage that might occur at specified quantity-distances if there was an explosion in the melt-pour building. Reliability was assumed to be a function of the Mean-Time-Between Explosions (MTBE) in years, and the proposed processes were compared with the current process at six LAP lines, using a two part model to simulate each facility-reliability (MTBE) combination and to provide comparative results. The casualties and damage that occurred in the "assumed" explosion in each type of process were expressed as a function of the quantity-distances specified for the amount of explosion in the melt-tower building. A lack of information about the explosive accidents that have occurred at the melt-pour plants made it necessary to simulate the problem by parametrically assuming a range of MTBE's for the current process and the proposed processes. Each of the proposed processes was compared to the current process at nine conditions (all combonations of 10, 50, and 100 years MTBE for all processes). The results obtained with both models were based on 1000 iterations for each facility-process combination.

Part 1 of Model - The first part of the model simulated the activity of the current and the two proposed processes at each of six LAP lines (two each at Iowa, Joliet, and Milan AAP's) using MTBE values of 10, 50 and 100 years for each combination. The time to the next explosion was randomly selected from an exponential distribution described by the MTBE parameter, and only explosions occurring within a 10-year period of operation - the assumed economic life of the equipment - were used in this analysis.*

---

* For example, with sequentially random selection of three years: one year, five years, and two years, only the first three selections - a total duration of nine years - would be processed. This would result in assuming that explosions occurred in years three, five and nine for this trial. The later random selection of an MTBE of two years would not be considered since the total elapsed time of 11 years exceeds the imposed 10-year limit. Likewise, if the first random selection was 10 or 11 years, then no explosions would be assumed for this trial since the elapsed time equaled or exceeded the 10-year limit.

The triangular distributions of the fatalities, injuries, and property damage replacement cost were indirectly provided as inputs to the model by means of weighted factors applied to the location of the population (work force) and property at each of the 12 facility-process combinations. Each LAP line was divided into four casualty-damage zones whose limits were established, as shown in Appendix E, by the unbarricaded quantity-distances required for the maximum explosive limits assumed for the melt-pour building of each process.

When the Milan process is used, the monitor personnel will be in a blast-proof protective cell either within or very near the melt-pour building. For computation purposes, these operators were considered to be located within a less sensitive zone.

For each facility-process combination, distributions of the fatalities, injuries, and damage incurred were sampled for each explosion using the probabilities in Table B-1 which were based on estimates obtained from the ARMCOM Safety Office. The fact that these three distributions were related to each other through the magnitude of the explosion was considered by using the same random number to sample each of the distributions under the following rationale: Given a variable under consideration and an associated variable with a known (or assumed) degree of correlation, both expressed as statistical distributions, then

$$K = pm + (1 - p)\, n \qquad \text{(B.1)}$$

where:

K = the value of the resultant random number to be used to sample the distribution under consideration,

m = Value of random number which was selected in sampling the distribution of the associated variable,

n = Value of the new random number selected, and

p = Correlation coefficient expressing degree of correlation between the variable under consideration and an associated variable.

TABLE B-1

Distribution Parameters Used for Estimating

Casualties and Property Damage

DISTRIBUTION	PER CENT OF WORK FORCE AND PROPERTY DAMAGE REPLACEMENT COSTS ASSUMED TO BE EFFECTED IN CASUALTY-DAMAGE ZONES			
	Zone X	Zone A	Zone B	Zone C
Fatalities				
Maximum	100	50	10	1
Most Likely	100	10	0	0
Minimum	0	0	0	0
Disabling Injuries*				
Maximum	100	50	25	10
Most Likely	100	50	10	0
Minimum	50	10	0	0
Property Damage Replacement Costs				
Maximum	100	100	50	10
Most Likely	100	100	10	0
Minimum	100	0	0	0

* Per cent of population remaining after deduction of fatalities.

For a weak correlation ($p \rightarrow 0$), the random number K used to sample the distribution under consideration would approach n, i.e., the value of the new random number selected. However, in this analysis the correlation is assumed to be very strong ($p \rightarrow 1$) and, therefore, the random number K used to sample this distribution would approach m, i.e., the same random number would be used to sample both the distribution under consideration and the associated distributions. Triangular distributions were assumed for the conditional probabilities for the fatalities, injuries, and property damage replacement costs.

The costs for the fatalities and the disabling injuries were computed by multiplying the number of victims by the statutory planning costs used for Army contractor personnel in DA Circular 385-29 ($3,200 for a disabling injury and $75,000 for a fatality). Replacement costs for the property damage were derived from prorated adjustments of the line, support, and equipment (IPE) values obtained from the Master Layaway Plan maintained by AMSAR-PPI-W. The total cost for each facility-process combination is the summation of the costs for fatalities, injuries, and property damage. Discounted costs were also computed using a 10 percent annual discount factor and the accumulated time within each trial as shown:

$$f_d = \frac{1}{(1 + i)^t} \qquad \text{(B.2)}$$

where:

f_d = discount factor,

i = fractional interest, and

t = accumulated time in years.

The output results (expected value, the variance, and a histogram for each variable) are used as inputs for the second part of the model.

Part 2 of Model - This part used "Monte Carlo" techniques to compare the Part 1 results obtained for the proposed processes with those obtained for the proposed processes with those obtained for the current process. Distribution of the differences in fatalities, differences in injuries, and the differences discounted total replacement costs between the current and proposed processes were compared with the associated expected values in order to compute the variance. These differences were obtained by subtracting the randomly selected values for each of the proposed processes from their randomly selected equivalent for the current process. With this model, the variance is assumed to be independent so a random number can be selected for each sample drawn from each distribution.

This part also considered investment costs in addition to the inputs from Part 1. Independent and random samples were drawn from these triangularly distributed investment costs and divided into the difference of the discounted operating costs to obtain a savings investment ratio (SIR) for each facility-process combination. A distribution was also constructed for these ratios:

$$\text{Savings Investment Ratio} = \left(\frac{\text{Discounted Difference in Operating Costs of Current and Proposed Processes}}{\text{Investment Cost of Proposed Process}} \right) \qquad \text{(B.3)}$$

The results of Part 2 were handled in a manner similar to those from Part 1 with an expected value, the variance, and a histogram computed for each of these variates:

- Reduction in fatalities
- Reduction in disabling injuries
- Reduction in cost
- Savings investment ratio (SIR)

The expected event and the probability of a specific event occurring for each of these variates were obtained from these outputs.

Flow Diagrams of Model

Flow diagrams of the model (Figures B-1, B-2, and B-3) have been included to illustrate the two-step approach used in simulating and comparing the current and proposed melt-pour processes. Figures B-1 and B-2 show Part 1, the portion of the model used to similate each location-process combination. Figure B-3 compared the Part 1 cost outputs from the current process with those from the new processes at each location. This part of the model also considered investment costs in order to calculate a savings investment ratio for each process comparison.

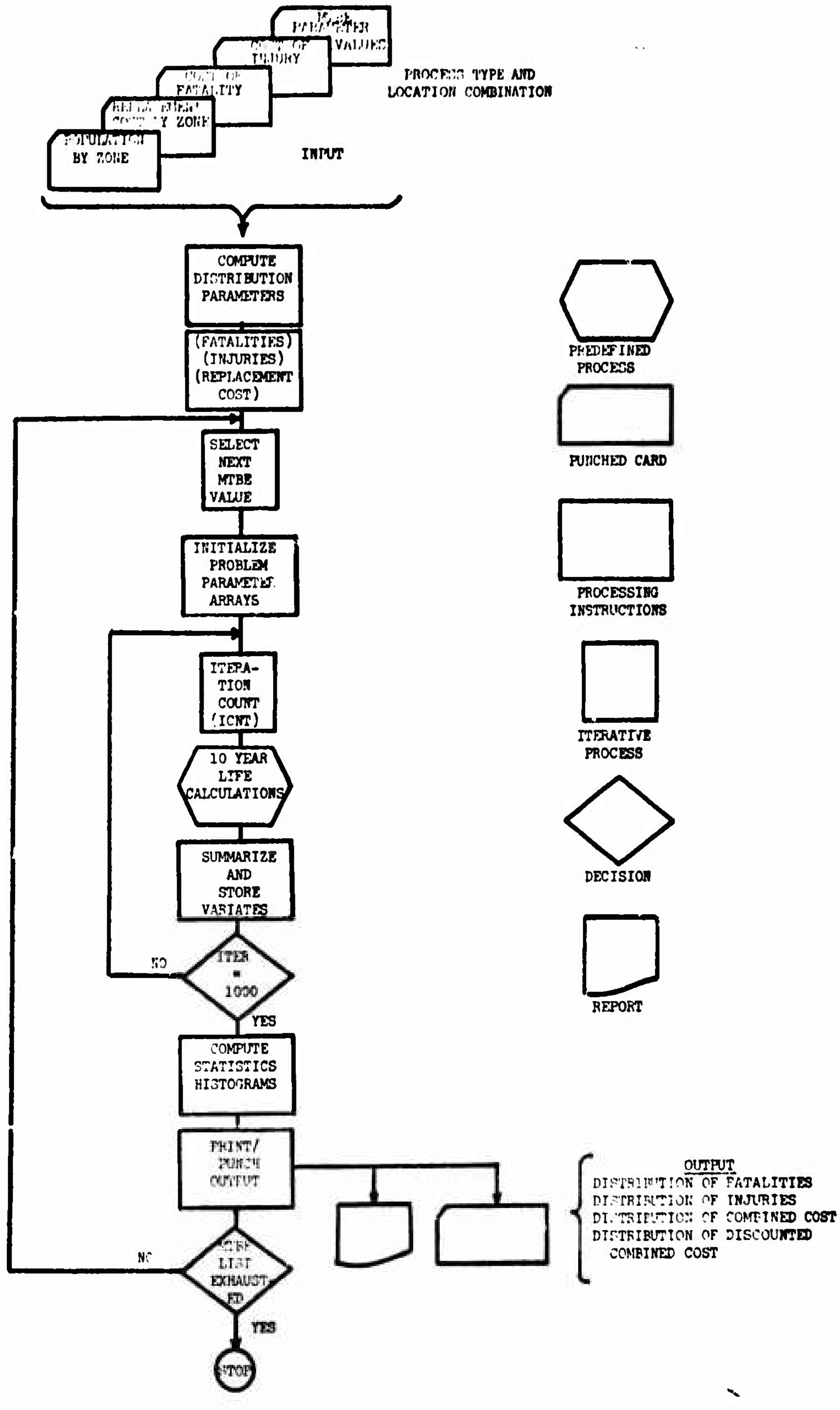

Figure B-1. Flow Diagram Model - Part 1

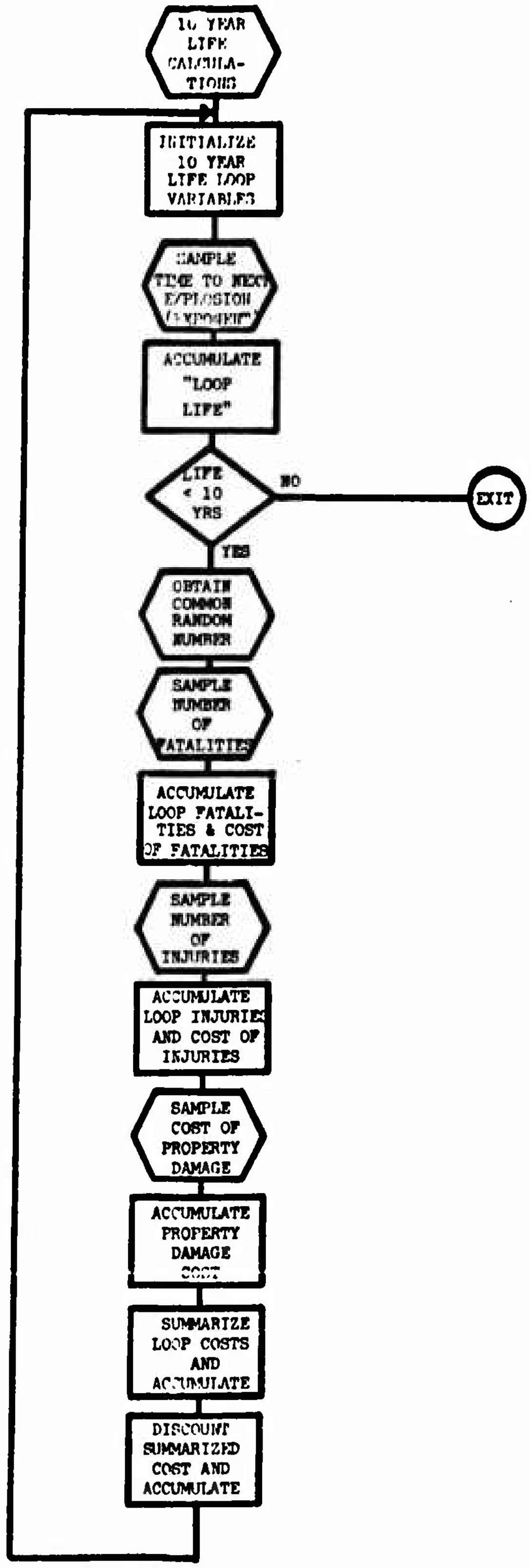

Figure B-2. Flow Diagram Model - Part 1 (10 Year Life Calculations)

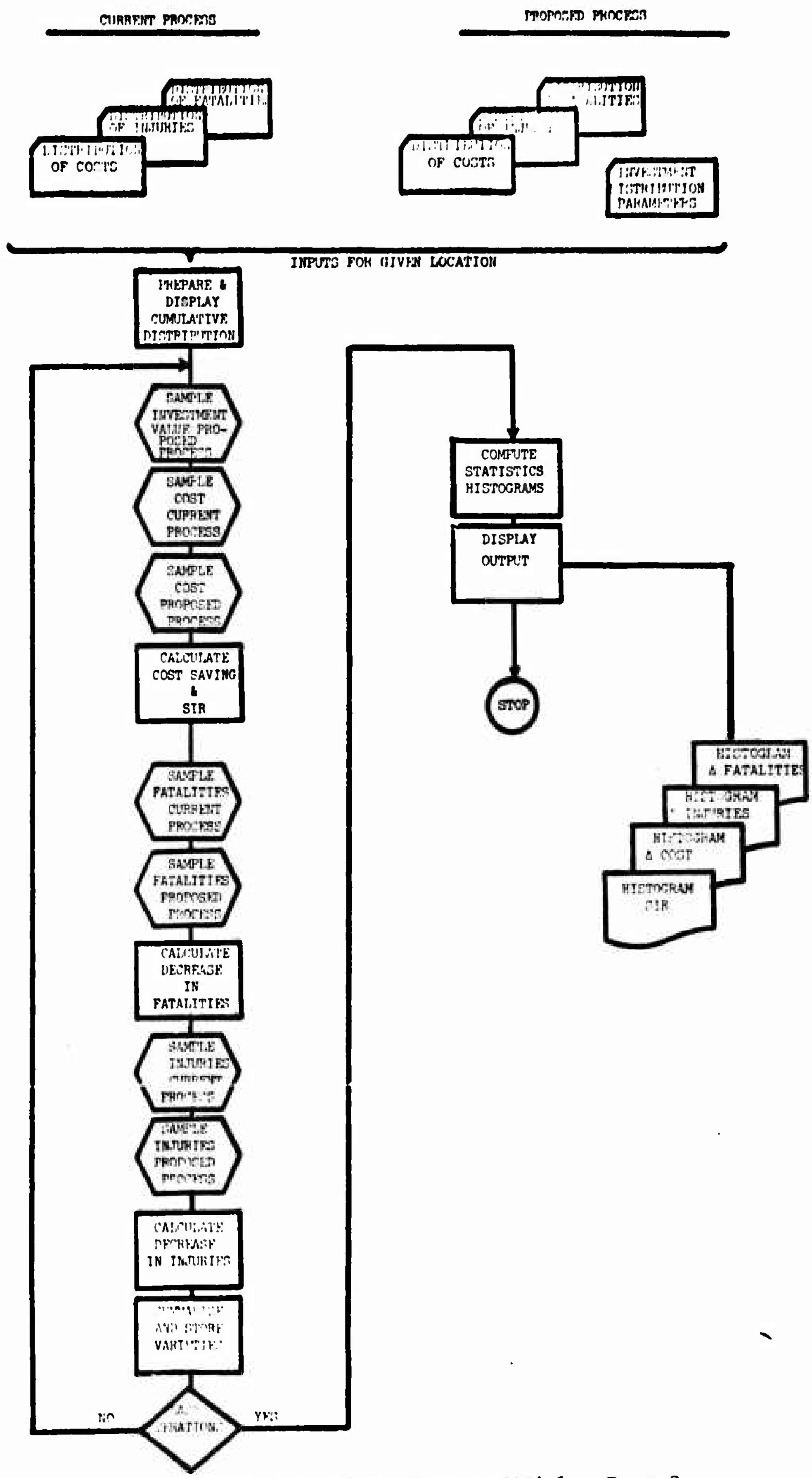

Figure B-3. Flow Diagram Model - Part 2

APPENDIX C

ANALYSIS INPUTS

This appendix lists the inputs used in the model to generate the distributions of the fatalities, disabling injuries, and property damage replacement costs for the respective process combinations.

The population (manning level) and replacement costs are listed in Tables C-1 through C-6 for the current processes and in Tables C-7 through C-18 for the proposed Picatinny and Milan processes, respectively.

TABLE C-1

Analysis Inputs for Part 1 of Model

Facility: Joliet AAP Group II

Process: Current

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	26	3606	580	4186
A	5	3175	132	449
B	13	8717	234	8951
C	28	4255	399	4654
TOTAL:	72	16895	1344	18239

TABLE C-2

Analysis Inputs for Part 1 of Model

Facility: Joliet AAP Group III

Process: Current

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	46	3115	1971	5086
A	0	574	919	1493
B	5	9013	0	9013
C	79	8284	1010	9294
TOTAL:	130	20986	3900	24887

TABLE C-3

Analysis Inputs for Part 1 of Model

Facility: Iowa AAP Line 2

Process: Current

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	18	2838	527	3364
A	0	3290	527	3817
B	0	9435	233	9669
C	53	14179	151	14330
TOTAL:	71	29743	1438	31180

TABLE C-4

Analysis Inputs for Part 1 of Model

Facility: Iowa AAP Line 3

Process: Current

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	9	2930	1689	4618
A	4½	2290	114	2405
B	11½	6430	634	7064
C	21	11933	46	11978
TOTAL:	46	23582	2483	26065

TABLE C-5

Analysis Inputs for Part 1 of Model

Facility: Milan AAP Line C

Process: Current

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	14	552	868	142
A	165	1950	688	2638
B	151	1657	540	2197
C	5	777	5	782
TOTAL:	335	4439	1320	5760

TABLE C-6

Analysis Inputs for Part 1 of Model

Facility: Milan AAP Line D

Process: Current

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	17	730	83	813
A	56	2140	248	2388
B	120	2912	812	3725
C	62	2138	1317	3456
TOTAL:	255	7920	2460	10380

TABLE C-7

Analysis Inputs for Part 1 of Model

Facility: Joliet AAP Group II

Process: Picatinny

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	0	637	983	1621
A	0	14	630	644
B	0	1366	909	2275
C	72	17249	2461	19710
TOTAL:	72	19267	4983	24250

TABLE C-8

Analysis Inputs for Part 1 of Model

Facility: Joliet AAP Group III

Process: Picatinny

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	0	637	983	1621
A	0	14	630	644
B	0	1383	9090	2292
C	130	20172	5028	25200
TOTAL:	130	22206	7551	29833

TABLE C-9

Analysis Inputs for Part 1 of Model

Facility: Iowa AAP Line 2

Process: Picatinny

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	0	637	983	1621
A	0	14	630	644
B	0	1366	909	2275
C	71	30103	2556	32659
TOTAL:	71	32121	5078	37199

TABLE C-10

Analysis Inputs for Part 1 of Model

Facility: Iowa AAP Line 3

Process: Picatinny

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	0	637	983	1621
A	0	14	630	644
B	0	1366	909	2275
C	46	23942	3601	27543
TOTAL:	46	23960	6123	32083

TABLE C-11

Analysis Inputs for Part 1 of Model

Facility: Milan AAP Line C

Process: Picatinny

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	0	637	983	1621
A	0	14	630	644
B	0	1366	909	2275
C	335	4840	2438	7279
TOTAL:	335	6857	4960	11819

TABLE C-12

Analysis Inputs for Part 1 of Model

Facility: Milan AAP Line D

Process: Picatinny

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	0	637	983	1621
A	0	14	630	644
B	4-1/4	1798	937	2735
C	250-3/4	7488	2433	9921
TOTAL:	255	9937	4983	14920

TABLE C-13

Analysis Inputs for Part 1 of Model

Facility: Joliet AAP Group II

Process: Milan

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	0	542	375	917
A	0	0	0	0
B	0	65	332	397
C	72	16895	1344	18239
TOTAL:	72	17502	2051	19553

TABLE C-14

Analysis Inputs for Part 1 of Model

Facility: Joliet AAP Group III

Process: Milan

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	0	542	375	917
A	0	0	0	0
B	0	65	332	397
C	130	20986	3900	24887
TOTAL:	130	21593	4607	26201

TABLE C-15

Analysis Inputs for Part 1 of Model

Facility: Iowa AAP Line 2

Process: Milan

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	0	542	375	917
A	0	0	0	0
B	0	65	332	397
C	71	29743	1438	31180
TOTAL:	71	30350	2145	32494

TABLE C-16

Analysis Inputs for Part 1 of Model

Facility: Iowa AAP Line 3

Process: Milan

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	0	542	375	917
A	0	0	0	0
B	0	65	332	397
C	46	23582	2483	26065
TOTAL:	46	24189	3190	27379

TABLE C-17

Analysis Inputs for Part 1 of Model

Facility: Milan AAP Line C

Process: Milan

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	0	542	374	916
A	0	0	0	0
B	0	65	332	397
C	335	4439	1320	5760
TOTAL:	335	5046	2026	7073

TABLE C-18

Analysis Inputs for Part 1 of Model

Facility: Milan AAP Line D

Process: Milan

ZONE	POPULATION	REPLACEMENT COSTS ($1000) BUILDINGS	EQUIPMENT	TOTAL
X	0	542	374	917
A	0	0	0	0
B	0	65	332	397
C	255	7920	2461	10380
TOTAL:	255	8527	3166	11694

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APPENDIX D

COMPARATIVE RESULTS OF

PROCESS COMBINATIONS

Results were obtained at three levels of reliability (MTBE's of 10, 50 and 100 years) for 12 proposed combinations to determine the potential effect of the proposed replacements on the reliability of six current melt-pour operations.

Each comparison of a current and a replacement process produced nine possible combinations of expected results as follows:

Tables D-1 - D-3	Fatalities:	Expected decrease, probability of decrease, risk of increase
Tables D-4 - D-6	Disabling Injuries:	Expected decrease, probability of decrease, risk of increase
Tables D-7 - D-12	Replacement Cost:	Expected decrease, probability of decrease, risk of increase
Tables D-13 - D-16	Savings Investment Ratio:	Expected value, probability of achieving SIR $\geq$ 1.0

TABLE D-1

EXPECTED DECREASE IN FATALITIES
DURING A 10-YEAR PERIOD IF CURRENT
PROCESS IS REPLACED BY PICATINNY OR MILAN PROCESS
(% OF MANNING LEVEL)

MEAN-TIME-BETWEEN-EXPLOSIONS FOR REPLACEMENT PROCESS (Years)	MEAN-TIME-BETWEEN-EXPLOSIONS FOR CURRENT PROCESS (Years)					
	100	50	10	100	50	10
JOLIET	**Group 2**			**Group 3**		
100	1.6	3.3	16.5	3.0	6.1	30.3
50	1.6	3.3	16.5	2.9	6.0	30.1
10	1.2	2.9	16.1	2.2	5.3	29.4
IOWA	**Line 2**			**Line 3**		
100	1.2	2.4	11.8	0.5	1.0	5.3
50	1.1	2.3	11.7	0.4	1.0	5.3
10	0.7	1.9	11.3	0.2	0.7	5.0
MILAN	**Line C**			**Line D**		
100	4.3	9.0	44.5	1.7	4.0	20.1
50	4.0	8.7	44.2	1.5	3.7	19.9
10	2.2	6.3	42.3	0	2.1	18.2

TABLE D-2

PROBABILITY OF DECREASE IN FATALITIES DURING A 10-YEAR PERIOD IF CURRENT PROCESS IS REPLACED BY PICATINNY OR MILAN PROCESS

MEAN-TIME-BETWEEN-EXPLOSIONS FOR CURRENT PROCESS (Years) (columns); MEAN-TIME-BETWEEN-EXPLOSIONS FOR REPLACEMENT PROCESS (Years) (rows)

JOLIET

Replacement process (Years)	Group 2: 100	Group 2: 50	Group 2: 10	Group 3: 100	Group 3: 50	Group 3: 10
100	.094	.183	.638	.094	.187	.653
50	.094	.186	.646	.094	.183	.659
10	.094	.172	.653	.094	.183	.660

IOWA

Replacement process (Years)	Line 2: 100	Line 2: 50	Line 2: 10	Line 3: 100	Line 3: 50	Line 3: 10
100	.094	.186	.654	.094	.189	.656
50	.094	.183	.660	.094	.188	.662
10	.094	.187	.664	.094	.182	.641

MILAN

Replacement process (Years)	Line C: 100	Line C: 50	Line C: 10	Line D: 100	Line D: 50	Line D: 10
100	.094	.189	.647	.094	.188	.663
50	.094	.188	.659	.094	.188	.659
10	.092	.186	.632	.089	.188	.640

TABLE D-3

RISK OF INCREASE IN FATALITIES DURING
DURING A 10-YEAR PERIOD IF CURRENT
PROCESS IS REPLACED BY PICATINNY OR MILAN PROCESS

Plant	Line	Mean-Time-Between-Explosions for Replacement Process (Years)	Mean-Time-Between-Explosions for Current Process (Years): 100	50	10
JOLIET	Group 2	100	.000	.000	.000
		50	.160	.000	.000
		10	.100	.517	.000
	Group 3	100	.000	.000	.000
		50	.151	.000	.000
		10	.085	.425	.000
IOWA	Line 2	100	.000	.000	.000
		50	.041	.159	.000
		10	.368	.128	.000
	Line 3	100	.089	.000	.000
		50	.154	.074	.000
		10	.512	.445	.067
MILAN	Line C	100	.100	.000	.000
		50	.065	.080	.000
		10	.610	.480	.197
	Line D	100	.100	.079	.000
		50	.151	.120	.027
		10	.608	.266	.203

TABLE D-4

EXPECTED DECREASE IN DISABLING INJURIES
DURING A 10-YEAR PERIOD IF CURRENT
PROCESS IS REPLACED BY PICATINNY OR MILAN PROCESS
(%)

MEAN-TIME-BETWEEN-EXPLOSIONS FOR CURRENT PROCESS (Years)

Rows: MEAN-TIME-BETWEEN-EXPLOSIONS FOR REPLACEMENT PROCESS (Years)

JOLIET

	Group 2: 100	Group 2: 50	Group 2: 10	Group 3: 100	Group 3: 50	Group 3: 10
100	1.0	2.9	17.3	1.3	4.4	30.3
50	0.5	2.4	16.9	0.5	3.5	26.1
10	-3.2	-1.3	13.3	-6.2	-3.2	19.4

IOWA

	Line 2: 100	Line 2: 50	Line 2: 10	Line 3: 100	Line 3: 50	Line 3: 10
100	0.4	1.5	10.1	0.3	1.0	7.5
50	0.0	1.1	9.7	0.0	0.7	7.2
10	0.7	1.9	6.0	-2.4	-1.6	4.8

MILAN

	Line C: 100	Line C: 50	Line C: 10	Line D: 100	Line D: 50	Line D: 10
100	4.3	9.1	61.6	1.1	4.4	30.9
50	1.2	7.0	59.5	-0.5	2.8	29.3
10	-16.1	-10.3	42.2	-13.5	-10.3	16.3

TABLE D-5

PROBABILITY OF DECREASE IN DISABLING INJURIES
DURING A 10-YEAR PERIOD IF CURRENT PROCESS
IS REPLACED BY PICATINNY OR MILAN PROCESS

		MEAN-TIME-BETWEEN-EXPLOSIONS FOR REPLACEMENT PROCESS (Years)	MEAN-TIME-BETWEEN-EXPLOSIONS FOR CURRENT PROCESS (Years)		
			100	50	10
JOLIET	Group 2	100	.088	.175	.640
		50	.087	.175	.647
		10	.079	.157	.591
	Group 3	100	.089	.173	.652
		50	.088	.173	.616
		10	.062	.153	.545
IOWA	Line 2	100	.088	.173	.630
		50	.086	.172	.609
		10	.063	.143	.548
	Line 3	100	.088	.171	.652
		50	.086	.168	.642
		10	.072	.147	.579
MILAN	Line C	100	.088	.170	.627
		50	.087	.172	.631
		10	.072	.152	.632
	Line D	100	.088	.172	.631
		50	.088	.170	.616
		10	.062	.136	.558

TABLE D-6

RISK OF INCREASE IN DISABLING INJURIES
DURING A 10-YEAR PERIOD IF CURRENT
PROCESS IS REPLACED WITH PICATINNY OR MILAN PROCESS

MEAN-TIME-BETWEEN-EXPLOSIONS FOR REPLACEMENT PROCESS (Years)	MEAN-TIME-BETWEEN-EXPLOSIONS FOR CURRENT PROCESS (Years)					
	100	50	10	100	50	10
JOLIET	**Group 2**			**Group 3**		
100	.081	.079	.033	.082	.080	.030
50	.154	.133	.045	.155	.134	.073
10	.547	.527	.230	.556	.526	.288
IOWA	**Line 2**			**Line 3**		
100	.083	.079	.040	.083	.079	.036
50	.156	.146	.076	.086	.151	.066
10	.582	.536	.272	.570	.516	.257
MILAN	**Line C**			**Line D**		
100	.081	.079	.038	.082	.076	.044
50	.147	.133	.061	.088	.139	.077
10	.570	.591	.197	.588	.592	.263

TABLE D-7

EXPECTED DECREASE IN REPLACEMENT COSTS
(DISCOUNTED 10% PER ANNUM) DURING A 10-YEAR PERIOD
IF CURRENT PROCESS IS REPLACED BY PICATINNY PROCESS
($1000)

MEAN-TIME-BETWEEN-EXPLOSIONS FOR CURRENT PROCESS (Years) across; MEAN-TIME-BETWEEN-EXPLOSIONS FOR REPLACEMENT PROCESS (Years) down

JOLIET

	Group 2: 100	Group 2: 50	Group 2: 10	Group 3: 100	Group 3: 50	Group 3: 10
100	198	657	4114	290	874	5311
50	8	467	3924	80	664	5100
10	-1553	-1094	2363	-1941	-1357	3080

IOWA

	Line 2: 100	Line 2: 50	Line 2: 10	Line 3: 100	Line 3: 50	Line 3: 10
100	168	647	4650	146	575	4004
50	-102	377	4380	-65	361	3790
10	-2323	-1844	2159	-2144	[illegible]	1713

MILAN

	Line C: 100	Line C: 50	Line C: 10	Line D: 100	Line D: 50	Line D: 10
100	112	465	3162	16	265	2377
50	-79	275	2972	-174	74	2187
10	-1576	-1222	1475	-1723	-1475	638

TABLE D-8

EXPECTED DECREASE IN REPLACEMENT COSTS (DISCOUNTED 10% PER ANNUM) DURING A 10-YEAR PERIOD IF CURRENT PROCESS IS REPLACED BY MILAN PROCESS
($1000)

MEAN-TIME-BETWEEN-EXPLOSIONS FOR CURRENT PROCESS (Years) (columns); MEAN-TIME-BETWEEN-EXPLOSIONS FOR REPLACEMENT PROCESS (Years) (rows)

JOLIET

Replacement process (Years)	Group 2: 100	Group 2: 50	Group 2: 10	Group 3: 100	Group 3: 50	Group 3: 10
100	249	708	4166	335	920	5358
50	96	553	4013	118	702	5141
10	-1164	-705	2752	-1582	-998	3440

IOWA

Replacement process (Years)	Line 2: 100	Line 2: 50	Line 2: 10	Line 3: 100	Line 3: 50	Line 3: 10
100	232	712	4715	215	644	4074
50	12	492	4495	17	446	3876
10	-1718	-1239	2765	-1517	-1088	2343

MILAN

Replacement process (Years)	Line C: 100	Line C: 50	Line C: 10	Line D: 100	Line D: 50	Line D: 10
100	199	553	3251	102	350	2464
50	73	427	3124	45	204	2305
10	-795	-[illegible]	2256	-1192	-94[illegible]	1170

TABLE D-9

PROBABILITY OF DECREASE IN REPLACEMENT COSTS
DURING A 10-YEAR PERIOD IF CURRENT PROCESS
IS REPLACED BY PICATINNY PROCESS

Plant	Line	Mean-Time-Between-Explosions for Replacement Process (Years)	Mean-Time-Between-Explosions for Current Process (Years): 100	50	10
JOLIET	Group 2	100	.093	.175	.616
		50	.091	.171	.602
		10	.067	.125	.480
JOLIET	Group 3	100	.093	.174	.628
		50	.091	.172	.617
		10	.078	.129	.552
IOWA	Line 2	100	.092	.174	.644
		50	.089	.171	.625
		10	.073	.124	.526
IOWA	Line 3	100	.092	.174	.624
		50	.091	.171	.624
		10	.066	.112	.484
MILAN	Line C	100	[illegible]	[illegible]	.627
		50	.088	.167	.583
		10	.067	.118	.533
MILAN	Line D	100	.087	.171	.634
		50	.084	.163	.612
		10	.054	.106	.437

TABLE D-10

PROBABILITY OF DECREASE IN REPLACEMENT COSTS
DURING A 10-YEAR PERIOD IF CURRENT
PROCESS IS REPLACED BY MILAN PROCESS

MEAN-TIME-BETWEEN-EXPLOSIONS FOR CURRENT PROCESS (Years) (columns); MEAN-TIME-BETWEEN-EXPLOSIONS FOR REPLACEMENT PROCESS (Years) (rows)

JOLIET

Replacement process	Group 2: 100	Group 2: 50	Group 2: 10	Group 3: 100	Group 3: 50	Group 3: 10
100	.093	.175	.627	.093	.174	.608
50	.092	.177	.625	.093	.173	.613
10	.085	.156	.534	.083	.139	.895

IOWA

Replacement process	Line 2: 100	Line 2: 50	Line 2: 10	Line 3: 100	Line 3: 50	Line 3: 10
100	.093	.174	.652	.092	.173	.638
50	.087	.174	.634	.092	.173	.640
10	.074	.140	.578	.080	.136	.478

MILAN

Replacement process	Line C: 100	Line C: 50	Line C: 10	Line D: 100	Line D: 50	Line D: 10
100	.090	.171	.651	.093	.172	.649
50	.092	.167	.609	.086	.170	.632
10	.074	.153	.591	.059	.133	.514

TABLE D-11

RISK OF INCREASE IN REPLACEMENT COSTS DURING
A 10-YEAR PERIOD IF CURRENT PROCESS
IS REPLACED BY PICATINNY PROCESS

MEAN-TIME-BETWEEN-EXPLOSIONS FOR CURRENT PROCESS (Years) (columns); MEAN-TIME-BETWEEN-EXPLOSIONS FOR REPLACEMENT PROCESS (Years) (rows)

JOLIET

Replacement	Group 2: 100	Group 2: 50	Group 2: 10	Group 3: 100	Group 3: 50	Group 3: 10
100	.092	.078	.043	.095	.090	.040
50	.168	.151	.079	.163	.141	.072
10	.616	.576	.315	.570	.573	.239

IOWA

Replacement	Line 2: 100	Line 2: 50	Line 2: 10	Line 3: 100	Line 3: 50	Line 3: 10
100	.096	.083	.042	.097	.086	.041
50	.173	.154	.080	.159	.152	.077
10	.571	.583	.304	.619	.592	.313

MILAN

Replacement	Line C: 100	Line C: 50	Line C: 10	Line D: 100	Line D: 50	Line D: 10
100	.098	[illegible]	[illegible]	.100	.090	.044
50	.173	.148	.090	.175	.151	.087
10	.554	[illegible]	.224	.590	.573	.348

TABLE D-12

RISK OF INCREASE IN REPLACEMENT COSTS DURING A 10-YEAR PERIOD IF CURRENT PROCESS IS REPLACED BY MILAN PROCESS

Mean-Time-Between-Explosions for Replacement Process (Years)	Mean-Time-Between-Explosions for Current Process (Years): 100	50	10	100	50	10
JOLIET	Group 2			Group 3		
100	.091	.088	.041	.092	.085	.042
50	.170	.146	.073	.151	.147	.076
10	.549	.467	.284	.569	.569	.105
IOWA	Line 2			Line 3		
100	.096	.085	.035	.095	.089	.033
50	.164	.133	.069	.158	.148	.050
10	.605	.541	.236	.555	.573	.320
MILAN	Line C			Line D		
100	.096	.09[illegible]	.019	.096	[illegible]	.031
50	.167	.156	.076	.173	.153	.074
10	.567	.430	.158	.625	.533	.304

TABLE D-13

EXPECTED SAVINGS INVESTMENT RATIO (SIR)
DURING A 10-YEAR PERIOD IF CURRENT
PROCESS IS REPLACED BY PICATINNY PROCESS
(COSTS DISCOUNTED 10% PER ANNUM)

MEAN-TIME-BETWEEN-EXPLOSIONS FOR REPLACEMENT PROCESS (Years)	MEAN-TIME-BETWEEN-EXPLOSIONS FOR CURRENT PROCESS (Years)					
	100	50	10	100	50	10
JOLIET	**Group 2**			**Group 3**		
100	0.01	0.04	0.27	0.02	0.06	0.35
50	0.00	0.03	0.26	0.01	0.04	0.33
10	-	-	-	-	-	0.20
IOWA	**Line 2**			**Line 3**		
100	0.01	0.04	0.30	0.01	0.04	0.26
50	-	0.02	0.29	0.00	0.02	0.25
10	-	-	0.14	-	-	0.11
MILAN	**Line C**			**Line D**		
100	0.01	0.03	0.20	0.00	0.02	0.15
50	0.00	0.02	0.19	-	0.00	0.14
10	-	-	0.10	-	-	0.04

TABLE D-14

EXPECTED SAVINGS INVESTMENT RATIO (SIR)
DURING A 10-YEAR PERIOD IF CURRENT PROCESS
IS REPLACED BY MILAN PROCESS
(COSTS DISCOUNTED 10% PER ANNUM)

MEAN-TIME-BETWEEN-EXPLOSIONS FOR CURRENT PROCESS (Years)

MEAN-TIME-BETWEEN-EXPLOSIONS FOR REPLACEMENT PROCESS (Years)

JOLIET

	Group 2			Group 3		
	100	50	10	100	50	10
100	0.18	0.52	3.03	0.24	0.67	3.90
50	0.07	0.40	2.92	0.09	0.51	3.74
10	-	-	2.00	-	-	2.51

IOWA

	Line 2			Line 3		
	100	50	10	100	50	10
100	0.17	0.52	3.43	0.16	0.46	2.97
50	0.01	0.36	3.27	0.01	0.33	2.82
10	-	-	2.01	-	-	1.71

MILAN

	Line C			Line D		
	100	50	10	100	50	10
100	0.15	0.40	2.37	0.07	0.26	1.79
50	0.05	0.31	2.28	-	0.15	1.69
10	-	-	1.64	-	-	0.85

TABLE D-15

PROBABILITY OF ACHIEVING OR SURPASSING A SAVINGS INVESTMENT RATIO OF 1 DURING A 10-YEAR PERIOD IF CURRENT PROCESS IS REPLACED BY PICATINNY PROCESS (COSTS DISCOUNTED 10% PER ANNUM)

MEAN-TIME-BETWEEN-EXPLOSIONS FOR CURRENT PROCESS (Years) (columns); MEAN-TIME-BETWEEN-EXPLOSIONS FOR REPLACEMENT PROCESS (Years) (rows)

JOLIET

Replacement (Years)	Group 2: 100	Group 2: 50	Group 2: 10	Group 3: 100	Group 3: 50	Group 3: 10
100	0	.001	.040	.001	.004	.098
50	0	.001	.032	.001	.002	.084
10	0	.001	.033	.001	.002	.066

IOWA

Replacement (Years)	Line 2: 100	Line 2: 50	Line 2: 10	Line 3: 100	Line 3: 50	Line 3: 10
100	0	.001	.042	0	.001	.033
50	0	.001	.037	0	.001	[illegible]
10	0	.001	.028	0	.001	.026

MILAN

Replacement (Years)	Line C: 100	Line C: 50	Line C: 10	Line D: 100	Line D: 50	Line D: 10
100	0	0	.018	0	0	.001
50	0	0	.013	0	0	.001
10	0	0	.011	0	0	.001

TABLE D-16

PROBABILITY OF ACHIEVING OR SURPASSING A SAVINGS INVESTMENT RATIO OF 1 DURING A 10-YEAR PERIOD IF CURRENT PROCESS IS REPLACED WITH MILAN PROCESS (COSTS DISCOUNTED 10% PER ANNUM)

MEAN-TIME-BETWEEN-EXPLOSIONS FOR CURRENT PROCESS (Years)

MEAN-TIME-BETWEEN-EXPLOSIONS FOR REPLACEMENT PROCESS (Years)

JOLIET

	100	50	10	100	50	10
100	.083	.169	.627	.090	.174	.608
50	.084	.171	.625	.089	.173	.613
10	.076	.136	.534	.083	.139	.568
	Group 2			Group 3		

IOWA

	100	50	10	100	50	10
100	.093	.143	.652	.090	.173	.638
50	.087	.169	.634	.090	.173	.640
10	.074	.140	.578	.068	.136	.522
	Line 2			Line 3		

MILAN

	100	50	10	100	50	10
100	.076	.160	.604	.082	.147	.627
50	.078	.155	.609	.081	.121	.585
10	.062	.135	.591	.046	.109	.452
	Line C			Line D		

APPENDIX E

CASUALTY-DAMAGE ZONES

The safety potential of each melt-pour process was defined by estimates of the casualties and property damage that might occur if there was an explosion in the melt-pour building. Obtained from the ARMCOM Safety Office, these estimates were based on the following Class 7 explosive limits and unbarricaded quantity-distances*:

MELT-POUR PROCESS	MAXIMUM EXPLOSIVE LIMITS IN MELT-POUR BUILDING (lbs)	UNBARRICADED QUANTITY-DISTANCE FROM MELT-POUR BUILDING (Feet)	
		Intraline	Inhabited Building
Current	15,000	450	990
Picatinny	2,000	230	505
Milan	200	100	235

The quantity-distances represent the quantity of explosive material and distance-separation relationships which provide defined types of protection. These relationships are based on levels of risk considered acceptable for the stipulated exposures. Intraline refers to those processes accomplished within one operating line; the inhabited buildings are those buildings occupied in whole or in part by workers.

The quantity-distance relationships were used to divide each of the six LAP lines into the following zones for segrating the casualties and property damage:

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* AMCR 385-100. Safety Manual. Change 1, 14 October 1971. Class 7 is bulk high explosives, general purpose bombs and high explosive warheads.

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ZONE	AREA
X	Melt-pour building
A	Unbarricaded intraline distance excluding melt-pour building
B	Unbarricaded inhabited building distance outside of Zone A
C	Remainder of LAP line

These zones were established for each LAP line by plotting the unbarricaded intraline and inhabited building quantity-distance arcs on a "plot plan" furnished by the AAP. Manning levels also supplied by the plant showed the number and location of the personnel on each line. The site of the proposed process was considered to be remotely located from the rest of the line in accordance with the safety concepts for the LAP modernization program. Figure E-1 is an illustrative example of how one of the LAP lines was divided into the casualty-damage zones for the current process.

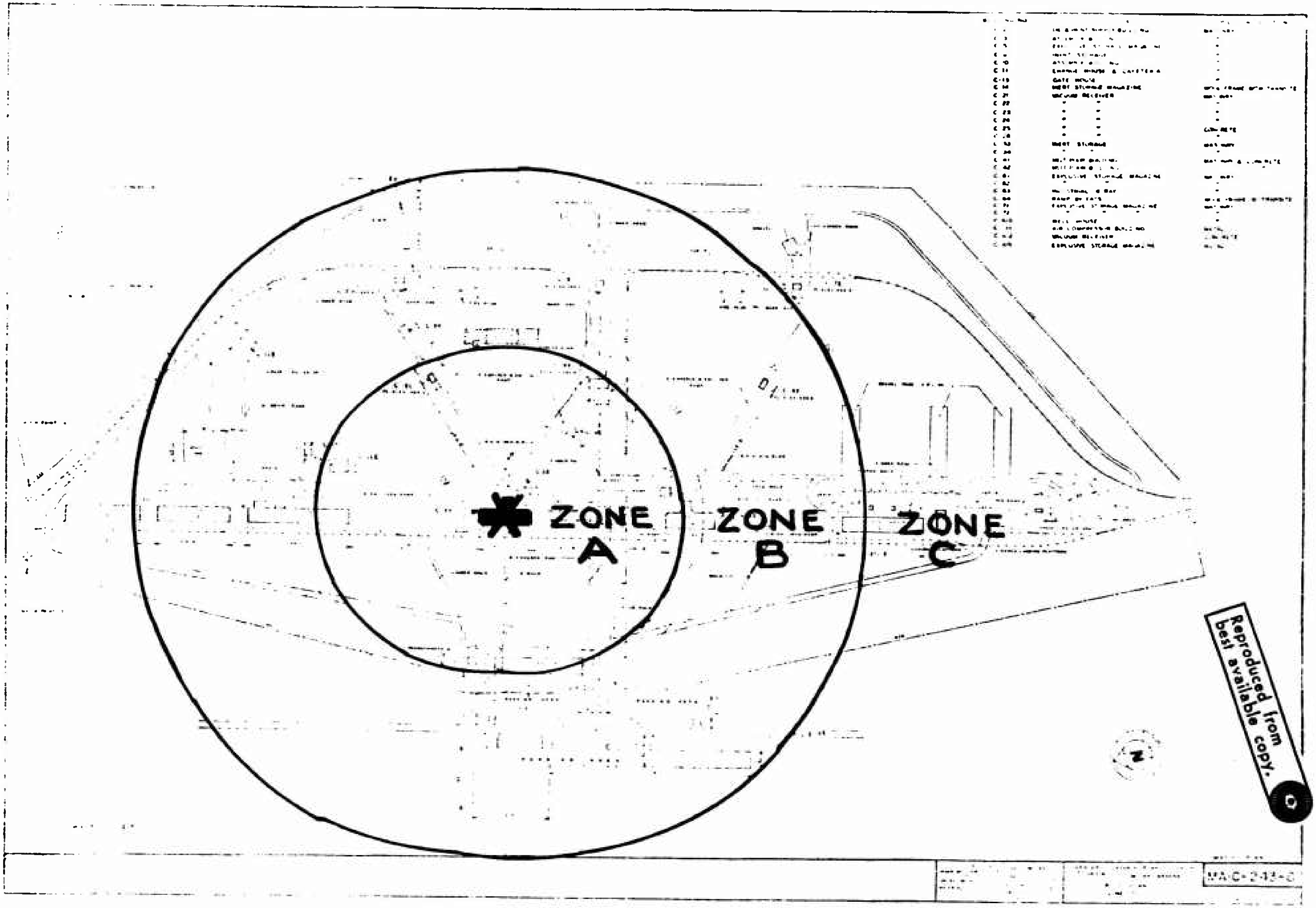

Figure E-1. How Casualty-Damage Zones were established for Current Process on Line C at Milan AAP.